

Review Article

Infection control after and during natural disaster

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We encounter many natural disasters in Japan and various infectious diseases could occur during and after natural disasters. Two recent major natural disasters, the Great East Japan Earthquake and the Kumamoto Earthquake in 2011 and 2016, respectively, killed tremendous numbers of people and many were affected with infectious diseases in evacuation centers as well as shelters for long period. Infection control teams of medical facilities inside or outside of affected areas were dispatched, supported evacuees, and made great contributions to: (i) control epidemic infectious diseases such as influenza and norovirus infection, (ii) educate and encourage people, (iii) improve environments. According to the experiences and evidence accumulated from these two disasters, it is apparent that infection control activities will definitely reduce infection during and after disasters. However, unlike the Disaster Medical Assistance Team and Japan Medical Association Team, there is no organization specialized for infection control in disaster-affected areas. A disaster infection control team should be established by leads of either of government and/or societies related to infectious diseases and infection control.

Key words: disaster ICT, disaster medical assistance team, infection, infection control, natural disaster

INTRODUCTION

JAPAN IS A country that is prone to encounter natural disasters such as typhoons, heavy rains, heavy snow, floods, sediment-related disasters, earthquakes, tsunamis, volcanic eruptions and others, compared to other countries. Japan's land area is only 0.28% of the whole world, but 20.5% of earthquakes with magnitude 6 or more have occurred in Japan, and 7.0% of the world's active volcanoes exist in Japan. In addition, 11.9% of the financial damage affected by disasters worldwide is sustained in Japan. Japan is a country with high proportion of disasters.¹

When natural disasters hit, some people lose their properties and are forced to live in evacuation centers or shelters. Dramatic changes of living circumstances among evacuees cause various infectious diseases due to many factors, such as stress, hygiene, and environmental issues. Additionally, when infrastructure such as water supply, electricity, and

gas supply are damaged, the risk of food poisoning is increased. Groups living in a confined place with insufficient ventilation easily leads to outbreaks of influenza, norovirus infection, tuberculosis, and others.

Emergency response by a Disaster Medical Assistance Team (DMAT) has been officially established to initiate activities immediately after the disaster happens. However, the organization or system of infection control in disaster-affected areas has not been established yet.

This review introduces the occurrence of infectious diseases after natural disasters in Japan, their countermeasures from the experiences of the Great East Japan Earthquake and Kumamoto Earthquake, and discusses what preparation is required for future natural disasters.

Damage caused by the Great East Japan Earthquake, occurrence of infection, and countermeasures

We encountered two major earthquake-related disasters in Japan, namely the Great East Japan Earthquake and the accompanying Fukushima nuclear accident, and the Kumamoto Earthquake in 2011 and 2016, respectively. In the Great East Japan Earthquake, a tsunami occurred following the earthquake and caused enormous damage. The number of dead exceeds 15,000 and approximately 2,500 people are still missing.

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When such disasters happen, the risk of epidemics of various infectious diseases increases.^{2–4} Wound infection from trauma, tetanus, gas gangrene, aspiration pneumonia, and Legionella pneumonia due to inhalation of contaminated water and other infectious diseases may happen immediately after a disaster involving a tsunami.⁵ Leptospirosis and Rickettsia diseases are also reported in the same phase (Fig. 1). Furthermore, after group living of evacuees in evacuation centers and shelters begins, close contact among people with insufficient ventilation and in non-hygienic situations can easily cause respiratory, gastrointestinal, and skin infections.⁵ Many of these infections caused by *Staphylococcus aureus*, group A streptococci, norovirus, adenovirus, and scabies, spread in shelters by contact. Droplet infections include influenza virus, *Mycoplasma pneumoniae* pneumonia, whooping cough, rubella, and mumps. Tuberculosis, measles, and varicella zoster virus spread as air-borne infections in affected areas.⁶

It is apparent that the infection control countermeasures at evacuation centers and shelters are extremely important. These countermeasures should be undertaken by local health centers and public health nurses. However,

due to disasters, the function of the public health center could be paralyzed, and the public health nurses could also be affected by the disaster. It is desirable to accept support from relatively large medical facilities, such as infection control teams of university hospitals from outside of disaster-afflicted areas. In fact, during the Great East Japan Earthquake and the Kumamoto Earthquake, some infection control teams from nearby university hospitals assisted the evacuation center and shelters. Unlike medical facilities, evacuation centers and shelters are places where ordinary people not familiar with infection control gather, and infection control countermeasures undertaken at medical facilities might be different from those taken in evacuation centers and shelters.

As actual infection control activities will be different depending on the kind, scale, and duration of the disaster, the form of the evacuation center, and the presence or absence of support, it is difficult to standardize countermeasures. However, in Japan, a country frequently hit by disasters, it is necessary to utilize or establish some guidance gained from past experiences for future generations. Universities and societies are indispensable in cooperation to establish this guidance.

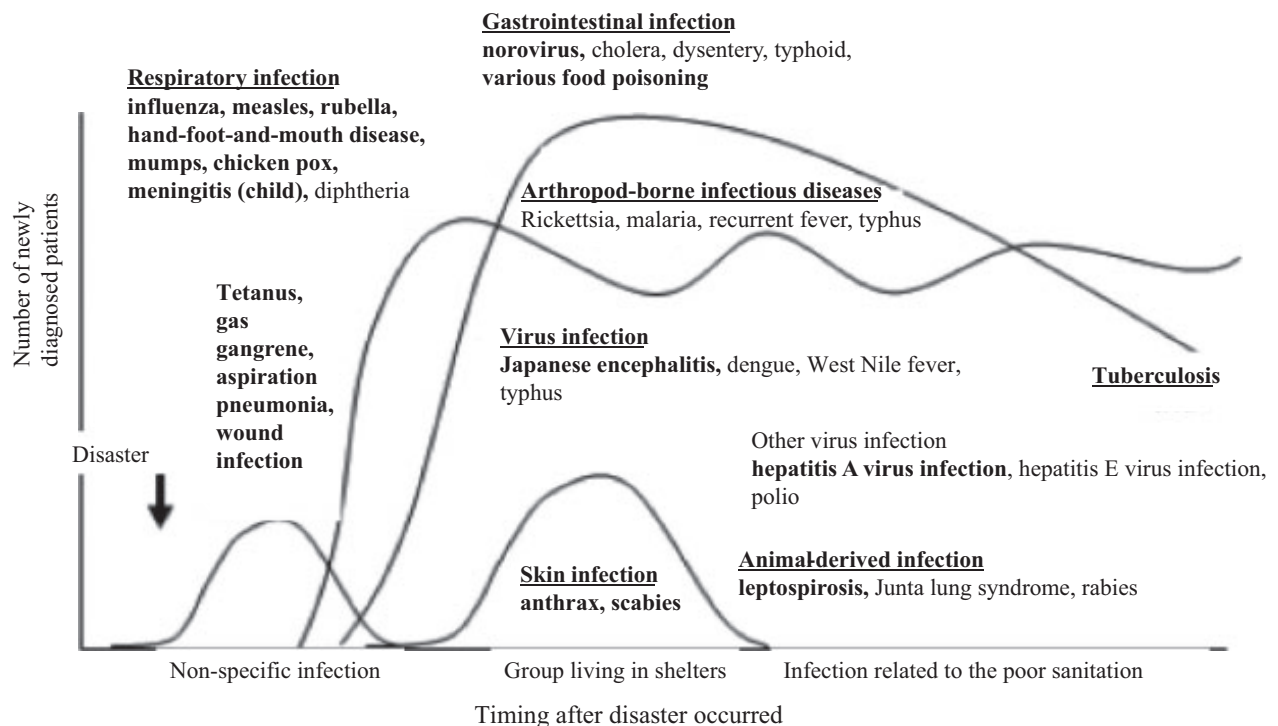


Fig. 1. Infection and onset period after natural disasters. Various infections may occur after natural disasters. They vary by the kinds and duration of disasters and time after onset. Infectious diseases and causative agents shown in bold are especially important in Japan.

In fact, during the Great East Japan Earthquake, various infection control countermeasures were executed, and Tohoku University's (Sendai, Japan) Tohoku Infectious Disease Crisis Management Network developed useful tools based on their experience at evacuation sites. These tools are available from their website free of charge: http://www.tohoku-icnet.ac/shinsai/hotline_iryuu.html.

Hatta *et al.* from Tohoku University reported that there are two major roles for infection control teams at disaster-affected areas: (i) preventive measures such as round and patrol in evacuation centers and shelters to assess the sanitation risk, (ii) quick response and undertake countermeasures corresponding to outbreaks, such as influenza infection.⁴ As a precautionary measure, risk assessment based on patrolling evacuation centers and shelters seems to be primarily important and it is desirable to establish a surveillance system detecting any signs of outbreak by prefectural health centers and/or the Ministry of Health, Labor and Welfare of Japan throughout the affected areas.

The "risk assessment on infection control in evacuation centers" developed by Tohoku University is an excellent tool that enables even those who are not a professional of infection control to assess the status to some extent. The main evaluation factors in risk assessment of evacuation centers and shelters include: (i) the size of evacuation centers, (ii) the number of inmates, (iii) the age composition of evacuees, (iv) hand hygiene adherence, (v) waste disposal, (vi) staff management, (vii) physical condition management, (viii) hygiene supplies, (ix) morbidity status, and others. A Japanese check list of risk assessment of evacuation centers and shelters can be downloaded from http://www.tohoku-icnet.ac/shinsai/hotline_iryuu.html.

While undertaking assessments at shelters and evacuation centers, it is possible to pick up more specific requirements according to each shelter.

Multiple measures against influenza infection, such as hand hygiene, reinforcement of cough etiquette, mask distribution, enlightenment posters, isolation of affected individuals, screening of infected persons with rapid diagnosis kits, and prophylaxis with anti-influenza drugs, were carried out diversely and worked very well after the Great East Japan Earthquake.^{4,7}

Flexible countermeasures according to each site were also required, and it was proven that infection control, especially outbreak response in hospitals, was fully utilized in evacuation centers and shelters.

Additionally, such an outbreak can be happen at any time, and anywhere, and it is expected that there will be a shortage of personnel who can undertake infection control countermeasures covering all affected areas; support from outside of the affected area is extremely important.

Damage and infectious diseases in the Kumamoto Earthquake, countermeasures and activities of Nagasaki University Infection Control Team

In April 2016, there were earthquakes of magnitude 6 or more with the epicenter in the Kumamoto district. Extensive damage occurred, and the number of deaths was approximately 50. Many victims were unable to return to their homes due to collapses of houses with continuation of aftershocks in Kumamoto city, Aso district, and Western Oita prefecture.

The evacuees exceeded 180,000 and a total of nearly 900 evacuation centers and shelters were built. Although there was no damage similar to the tsunami that happened in the Great East Japan Earthquake, it was a disaster that showed different characteristics, such as aftershocks that lasted for a long time. A week after the first earthquake, a norovirus outbreak was reported at an evacuation center in Minami-Aso, and the correspondence became an urgent issue (Data S1). With this outbreak, an organization centered on Nagasaki University Hospital Infection Control Team (Nagasaki, Japan) was formed, and a team was dispatched to Kumamoto Prefecture to control infection for the following 2 weeks.

Necessity of infection control anticipated from the onset of disaster

As the details of the damage became apparent several days after the onset of disaster, infection control countermeasures in affected areas were becoming a major concern. Unlike DMAT or a Japan Medical Association Team, organizations or teams specialized for infection control have not been sufficiently established. It seems that medical personnel who have no experience of disaster-related medical care probably possess limited ideas regarding what can be done for evacuees. Furthermore, even if asked for assistance, it is difficult to go to the affected sites and initiate assistance due to lack of experience and knowledge.

Coverage of norovirus outbreaks in Minami-Aso and establishment of the Aso District Disaster Medical Recovery Organization Infection Control Team

As Nagasaki University Hospital received requests to support affected areas from the Kumamoto Prefecture Disaster Countermeasures Headquarters through Nagasaki Prefecture, Nagasaki University DMAT was dispatched to Kumamoto City right after the first earthquake. The teams were then transferred to Aso District Disaster Medical Recovery



Fig. 2. Members of the Aso Disaster Recovery Organization Infection Control Team. A, Members of the Fukuoka and Kumamoto Self Defense Force Hospitals from Fukuoka and Kumamoto, respectively. B, Members of Sakura General Hospital from Aichi Prefecture.

Organization (ADRO) a couple of days after onset (Data S2). The ADRO covered all of Aso city and Nishihara and Minami-Aso districts and provided medical assistance to all areas requested from Aso Health Center. Approximately 1 week after the first earthquake, an outbreak of norovirus was reported at a large evacuation center occupied by more than 500 people in Minami-Aso (Data S1). There was no infection control expert at ADRO headquarters when this outbreak was reported. There was an urgent request from the medical assistance team of Nagasaki University Hospital in ADRO to Nagasaki University Hospital Infection Control and Education Center to assist the affected evacuation center as well as other centers and shelters. A director doctor and infection control nurse was dispatched to ADRO headquarters immediately and the new team, namely the ADRO Infection Control Team (ICT) to begin infection control countermeasures. The team of Nagasaki University Hospital, Fukuoka and Kumamoto Self Defense Force Hospitals from Fukuoka and Kumamoto prefectures, respectively, and the team from Sakura General Hospital from Aichi Prefecture joined the ADRO ICT (Fig. 2). Several vehicles were deployed and activities began over a vast area. This was first time that the combined infection control team consisted of a university; the Self Defense Force and private hospitals were established and initiated activity during disasters in Japan.

Activities of ADRO ICT

Controlling the outbreak of norovirus and initiation of infection control at evacuation centers and shelters under the jurisdiction of ADRO were the primary goals of ADRO ICT. When ADRO ICT started its activities, nearly 50 evacuation centers and shelters were confirmed in the affected area and it was difficult for ADRO ICT members to reach each shelter due to interruption of the roads destroyed by continuous earthquakes.

The evacuation center where the norovirus outbreak occurred in Minami-Aso had already been equipped with

adequate sanitary supplies and water, and other DMATs had been involved in infection control countermeasures as well. The individuals infected with norovirus were isolated and enhancement of hand hygiene was promoted with many posters on the walls. Since evacuees with less knowledge of norovirus infection were under high stress because of the aggressive infection control countermeasures, ADRO ICT modified the excess countermeasures and explained what infection control countermeasures meant to relief evacuees.

At the same time, ADRO ICT started risk assessment of other evacuation centers and shelters to prevent similar outbreaks. We used “risk assessment on infection control in the shelter” checklist with adding confirmation of the existence of isolation rooms for Norovirus or influenza infected individuals. Additionally, ADRO ICT decided to roll out the activities to distribute the “nine tips for infection prevention” poster (Data S3), created by Kumamoto Prefecture, to all evacuation centers and shelters. The nine tips are: (i) try to eat heated food as much as possible, (ii) drink clean water only and use clean cups and glasses, (iii) hand hygiene with water or alcohol before eating and after using restrooms, (iv) used diapers should be wasted in designated area and wash hands after changing diapers, (v) take off your shoes when entering living sections in shelters, (vi) conduct cough etiquette, (vii) consult a doctor, nurse, or manager of the site when you have upper respiratory symptoms, fever, nausea, vomiting, and abdominal symptoms, especially when you feel that an increasing number of individuals are complaining of same symptoms, (viii) wear a mask if you have fever and/or cough or taking care of such individuals, (ix) consult a doctor, nurse, or manager of the site in case you have possible pneumonia with symptoms such as severe cough, yellowish sputum, dyspnea, malaise, and a pale complexion.

At the same time of assessment, ADRO ICT attempted to establish a surveillance system to grasp the outbreaks. However, the route by which information of influenza and norovirus infections was passed to ADRO ICT was



Fig. 3. Arrangement of distribution of sanitary substances to evacuation centers and shelters following the Kumamoto Earthquake, 2016. A, Photograph of a meeting of the Aso Disaster Recovery Organization Infection Control Team (ADRO ICT). B, Photograph of transportations of sanitary supplies by ADRO ICT vehicles.

unclear and the information was also complicated. Initial quick response is important for controlling outbreaks and starting countermeasures not only in hospitals but also in evacuation centers and shelters. Although it is essential to collect accurate information, constructing a surveillance system is difficult in cases of emergency.

Continuation of assessment and establishing a surveillance system

The ADRO ICT vigorously carried out assessments of evacuation centers and shelters. Finally, it took almost 4 days to complete the infection risk assessment of all 90 evacuation centers and shelters, including facilities for the elderly. Due to limited manpower and transportation, ADRO ICT concluded that it is difficult to uniformly intervene at all evacuation centers and shelters. Based on the assessment results, we divided the risk of infectious disease and outbreak onset into “high,” “moderate,” and “low” for each center and shelter and initiated intensive intervention to “high” risk shelters. “High” risk was mainly defined as a loss of availability of water and rest rooms in evacuation centers and shelters. “Low” risk defined evacuation shelters that were equipped with many sanitation items without loss of water supply and toilets. “Moderate” defined evacuation centers and shelters in which there were not enough sanitation items without loss of water and toilets.

The interventions at “high” risk evacuation centers and shelters were mainly on introducing sanitary items such as alcohol sanitizers and soaps, enhancement of hand hygiene, improvement of environments such as toilets, kitchen, and food sanitation, waste management, and establishing the management of shelters. The ADRO ICT made great contributions to making arrangements to distribute sanitary substances preferentially by their several automobiles (Fig. 3). In establishing a surveillance system, the liaison leaders of the three areas of ADRO’s

2016.4.27 19:00

毎日:1200更新

過去24時間発生した 新規感染者 (注:未発表)		昨日までの累積感染者		
インフル	ノゾ	インフル	ノゾ	
阿蘇	0 (0)	1 (0)	0	1
南阿蘇	1 (2)	0 (3)	5	3
西原	0 (0)	0 (0)	0	0

南アソ中 1

かんぽ 会長

Fig. 4. Reporting system of surveillance of norovirus infection and influenza. Photograph posted on the wall of Aso Disaster Recovery Organization (ADRO) headquarters indicating the number of individuals infected with norovirus or influenza virus in the three ADRO jurisdiction areas following the Kumamoto Earthquake, 2016.

jurisdiction aggregate information of norovirus infection and influenza by 12:00 every day to capture the outbreak. The information was also shared to everybody in ADRO at daily meetings held at 18:00 (Fig. 4).

Establishment of infection control manual at evacuation centers accompanying the ADRO ICT

As the information on each evacuation center and shelter gradually accumulated and the surveillance began functioning well, inquiries regarding infection control details from the evacuation shelters and shelters increased. For example, methods of cleaning toilets, criteria for isolation of individuals with norovirus and influenza virus, and quarantine release criteria. There was no person in charge of infection control at the evacuation centers and shelters, and many volunteers with various backgrounds enter and leave the shelters every few days. Initial infection control countermeasures introduced by ADRO ICT at the sites were easily changed and sometimes terminated. It was realized by ADRO ICT that uniform infection control countermeasures are difficult to implement in each center and shelter. Therefore, ADRO ICT decided to prepare a universal infection control manual, which is prepared in many medical facilities. The ADRO ICT utilized and modified a manual established by Tohoku University and downloaded from Tohoku University East Japan Great Earthquake infections hotline site (http://www.tohoku-icnet.ac/shinsai/hotline_iryoku.html).

Thereafter, at evacuation centers and shelters under the jurisdiction of ADRO, it was decided to use the manual made by ADRO ICT and introduced to each site. Most importantly, the crucial purpose was to minimize confusion at the evacuation centers and shelters and to undertake uniform and continuous infection control countermeasures.

Activities of the ADRO ICT, such as assessment, supply of sanitary substances, practice of infection control, education and instruction to managers and evacuees of evacuation centers and shelters, response to individual infectious disease cases, manual formulation, and other support activities in approximately 90 evacuation centers and shelters, including facilities for the elderly, were continued for 13 days. Fortunately, new outbreaks by norovirus and influenza virus did not occur after the establishment of ADRO ICT, and the role of ADRO ICT was handed over to the Kumamoto Prefecture Infection Control Network. This network was established by Dr. Tatsuya Kawaguchi, Kumamoto University, and mainly consisted of infection control nurses across Kumamoto Prefecture.

With the great cooperation of the Fukuoka and Kumamoto Self Defense Force Hospitals from Fukuoka and Kumamoto, respectively, Sakura General Hospital from Aichi Prefecture, and Nagasaki University Hospital, ADRO ICT achieved success in controlling infections in the affected area. Without the coordination of these teams, ADRO ICT could not have achieved its primary goals.

The necessity of establishment of disaster ICT (DICT) organizations consisting of university and private hospitals and the Self Defense Force is warranted. Based on the lessons learned from the Great East Japan Earthquake and Kumamoto Earthquake, the Japan Environmental Infection Association is currently planning the establishment of DICT and preparing the revised version of the manual titled “Guidance of infection control management of areas affected by large-scale natural disasters.”

CONCLUSION

AFTER AND EVEN during natural disasters, a variety of infectious diseases could occur at various times, depending on the kinds of natural disasters. In the situation of human and material scarcity at the affected area, it is required to establish a nationwide organization, a so-called DICT, which enters the affected area from outside and undertakes infection control countermeasures to support local health authorities and evacuees.

DISCLOSURES

Approval of the research protocol: N/A.

Informed consent: N/A.

Registry and registration no. of the study/trial: N/A.

Animal studies: N/A.

Conflict of interest: None.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Data S1. Newspaper report of norovirus outbreak in the evacuation center in Minami-Aso following the Kumamoto Earthquake, 2016

Data S2. Aso Disaster Recovery Organization (ADRO)

Data S3. Poster for all evacuees to enhance the prevention of infection following the Kumamoto Earthquake, 2016